Introduction

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Welcome to the November 2020 special issue of *Civil Engineering* on the Great Western railway electrification in the UK.

Completed in January 2020, this £3 billion programme of works involved threading overhead line equipment along 650 km of live railway tracks and through dozens of historic bridges and tunnels. It has enabled new quiet, efficient and reliable electric trains to run between London Paddington and Cardiff in South Wales, delivering significant environmental and service benefits.

The seven papers in this issue describe many of the challenges and lessons learned in delivering this huge programme – the first major electrification scheme in the UK for a generation.

Two further papers on the project (Manis and Richardson, 2020; Nolan, 2020) will appear in subsequent regular issues of this journal.

Background

The Great Western electrification programme (GWEP) was a substantial part of a wider upgrade of the Great Western railway.

The overall route modernisation included: Reading station redevelopment (Warrior *et al.*, 2015); a large re-signalling project around the Bristol area; increasing capacity between Bristol Parkway and Bristol Temple Meads stations; works around Oxford station; and introducing new electric and bi-mode (diesel and electric) trains.

The modernisation needed to be delivered in stages to support the largest timetable change on the Great Western route since the 1970s. The electrification started in 2007 and the new timetable was successfully delivered on 15 December 2019.

The first stage was the Intercity Express Programme, which was set up to procure new electric and bi-mode trains to replace the route's aging InterCity 125 diesel trains, and electrification of the route was announced in July 2009. Prior to this, the only electrified section was a 19 km section from Paddington.

Great Western was the last main-line diesel route in the UK and, with overcrowding set to rise on an already packed service into Paddington from the west, more capacity was needed. The diesel InterCity 125 trains were also unreliable, expensive to run, noisy and a significant source of carbon dioxide emissions. They needed to be replaced with electric and bi-mode trains to meet the Department for Transport's carbon strategy and the Climate Change Act 2008, which aims for net zero emissions by 2050.

Electric trains have many benefits. They are:

- better for the environment, emitting 20–35% less carbon dioxide per passenger kilometre than diesel trains (Department for Transport, 2009)
- cleaner, having zero emissions at the point of use and, with regenerative braking, are more energy efficient
- quieter, reducing noise pollution for those living and working near the tracks and reducing noise and vibration for passengers
- cheaper, costing 35% less to operate than diesel trains (Network RUS, 2009)

- quicker, improving journey times due to superior braking and acceleration
- lighter, reducing the cost of track maintenance
- more reliable, reducing passenger delays.

Changing scope

Various government decisions changed the scope of the electrification programme. In 2009, the electrification proposals extended to Swansea in South Wales, but the 2011 coalition government stopped it at Cardiff. The decision was reversed in 2012, when the government announced electrification of the Cardiff–Swansea line along with electrification of lines between Acton and Willesden, Slough and Windsor, Maidenhead and Marlow, and Twyford and Henley on Thames (for a route section map see Griffiths *et al.* (2020)).

Affordability mattered and electrification was becoming expensive, so various reviews were undertaken. The most notable of these are known in the UK railway industry as the Bowe Review (Department for Transport, 2015); the Hendy Report (Department for Transport, 2016); the National Audit Office Report (National Audit Office, 2016); and a Public Accounts Committee Review (House of Commons Committee of Public Accounts, 2017).

The result of the reviews was that the Great Western electrification would only cover the routes from London to Cardiff (via Reading, Didcot, Swindon, Bristol Parkway and Newport), from Reading to Newbury and from Swindon to just east of Chippenham. This was due to the ability of the new bi-mode trains being seamlessly able to switch from electric to diesel. The reviews also informed the decisions to defer from the then control period 5 (2014–2019) to control period 6 (2019–2024), the routes from Chippenham to Bristol Temple Meads, from Bristol Parkway to Bristol Temple Meads and from Didcot to Oxford, all of which are awaiting agreement to restart.

A number of lessons were learnt from the reviews including: improving the way multi-interface large programmes are integrated with each other; the way rail electrification projects are costed; and how rail enhancements are detached from the control period timeframes and spending, being progressed collaboratively between Network Rail and the Department for Transport through a new staged-investment model.

Engineering innovation

It was three decades since electrification on such a scale had been undertaken in the UK. The existing technology was old, so Network Rail and Furrer & Frey embarked on the development of a new overhead line equipment system, called 'Series 1', and new power distribution and control systems. Together these eliminated over 90 reliability issues of existing UK systems. For example, Great Western was the only overhead line system in the UK not affected by the 2019 heatwave.

New transformers were introduced that could feed 200 km of route, improving power reliability, diversity and resilience. A new rationalised autotransformer system developed within Network Rail, supported by ABB, UK Power Networks and Siemens, provided digital fibre-optic communication and control technology based on the IEC 61850 protocol (IEC, 2020). This reduced the number of high-value circuit breakers required, minimised the length of track affected by isolating a fault and made it easier to pinpoint and rectify faults. The system won an innovation award at the UK National Rail Awards in 2018.

To help deliver the 13 000 support structures (Esser and Lethbridge, 2020) and 650 km of electrical wiring, Network Rail bought a £40 million state-of-the-art installation train from Windhoff in Germany. With a top speed of 96 km/h, the so-called 'Hops' (high-output plant system) train was made up of 23 vehicles forming five trains: to build foundations for the overhead line structures; to install the steelwork such as stanchions, booms and arms; and for the final stages of wiring. The train, which had additional safety features that permitted it to operate with the adjacent line open, delivered around 15 foundations and stanchions per 8 h railway possession.

During the design phase, Network Rail challenged the interpretation of standards relating to loads applied to overhead line equipment support structures. To improve the economy, safety and performance of overhead line equipment, it undertook a research programme with the University of Southampton. The result was an improved and more realistic design for UK locations (Powrie *et al.*, 2019).

Railway standards were also challenged through risk-based design used at both Steventon overbridge (Baimpas *et al.*, 2020) and Cardiff intersection bridge. The latter had tight clearances between the bridge soffit and overhead contact wire. Following a review of all options, the most cost-effective whole-life solution was to run the wire under the bridge at a lower than standard contact wire height, which required obtaining a deviation from group standard GL/RT1210 (RSSB, 2014). This was supported by a risk-based approach to design, modelling all rolling stock in use and future known stock, updating operational requirements for steam trains, and installing novel products such as surge arrestors and a polyurea electrically insulating coating. The result was a saving of millions of pounds in reconstruction costs and a significant reduction in programme time.

Building information modelling (BIM) was initially used to aid clash detection, but GWEP also managed and used BIM models for signal sighting, driver training and many other applications (Nolan, 2020).

Contracts and delivery

As with any mega project, a large number of contractors were involved in the delivery. Key contracts were let to Atkins, Parson Brinkerhoff, Arup, Amey, Balford Beatty, ABB, UK Power Networks, ABC (Alstom, Babcock, Costain) and Bechtel.

Many other designers, specialists and contractors were involved with each aspect, including a number undertaking the various route-clearance packages (Fletcher *et al.*, 2020; Jackson *et al.*, 2020; Manis and Richardson, 2020).

All contracts had to be carefully managed and coordinated including logistics, possessions, data management (Berryman and Cheung, 2020) and commissioning (Griffiths *et al.*, 2020). Finally, Network Rail worked collaboratively with train operator Great Western Railway to avoid disruption to passengers and ensure minimal impact on the environment (Deschamps and Franklin, 2020).

My thanks go to all authors for sharing their experiences with us and to the independent peer reviewers for their invaluable input. Even if you are not directly involved in railways, I believe you will find many of the engineering challenges and solutions interesting, plus most of the lessons learned are relevant to all major infrastructure programmes.

References

- Baimpas N, Dearman P, Warren S *et al.* (2020) Great Western railway electrification, UK: pantograph interface model boosts speed. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **173(6)**: 19–27, <https://doi.org/10.1680/jcien.19.00056>.
- Berryman M and Cheung W (2020) Great Western railway electrification, UK: data challenges and visual solutions. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **173(6)**: 11–18, <https://doi.org/10.1680/jcien.20.00015>.
- Climate Change Act 2008. Chapter 27. The Stationery Office, London, UK
- Department for Transport (2009) *Britain's Transport Infrastructure: Rail Electrification*. Department for Transport, London, UK.
- Department for Transport (2015) *Report of the Bowe Review into the Planning of Network Rail's Enhancement Programme 2014–2019*. Department for Transport, London, UK.
- Department for Transport (2016) *Network Rail's Investment Programme: The Hendy Report Consultation*. Department for Transport, London, UK.
- Deschamps E and Franklin M (2020) Great Western railway electrification, UK: collectively delivering a sustainability strategy. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **173(6)**: 5–10, <https://doi.org/10.1680/jcien.20.00001>.
- Esser J and Lethbridge R (2020) Great Western railway electrification, UK: foundations for overhead line equipment. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **173(6)**: 47–53, <https://doi.org/10.1680/jcien.20.00017>.
- Fletcher N, Brown M and Sadek T (2020) Great Western railway electrification, UK: Patchway tunnels. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **173(6)**: 37–45, <https://doi.org/10.1680/jcien.20.00021>.
- Griffiths J, Jordan A and Gardner S (2020) Great Western railway electrification, UK: testing and commissioning. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **173(6)**: 55–62, <https://doi.org/10.1680/jcien.20.00012>.
- House of Commons Committee of Public Accounts (2017) *Modernising the Great Western Railway: Forty-fourth Report of Session 2016–17*. House of Commons, London, UK.
- IEC (International Electrotechnical Commission) (2020) IEC 61850: Communication networks and systems for power utility automation. IEC, Geneva, Switzerland.
- Jackson R, Elliot H, Cooke P *et al.* (2020) Great Western railway electrification, UK: civil engineering works. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **173(6)**: 29–36, <https://doi.org/10.1680/jcien.20.00030>.
- Manis P and Richardson P (2020) Great Western railway electrification, UK: Bridge Street overbridge reconstruction. *Proceedings of the Institution of Civil Engineers – Civil Engineering*, <https://doi.org/10.1680/jcien.20.00020>.
- National Audit Office (2016) *Modernising the Great Western Railway*. National Audit Office, London, UK.
- Network RUS (Route Utilisation Strategy) (2009) *Network RUS: Electrification Strategy – Draft for Consultation*. Network Rail, London, UK.
- Nolan J (2020) Great Western railway electrification, UK: the key role of building information modelling. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **173(4)**: 158–170, <https://doi.org/10.1680/jcien.20.00011>.
- Powrie W, Richards D, Mootoosamy V (2019) The design of railway overhead line equipment mast foundations. *Proceedings of the Institution of Civil Engineers – Geotechnical Engineering* **173(5)**: 428–447, <https://doi.org/10.1680/jgeen.18.00242>.
- RSSB (Railway Safety and Standards Board) (2014) GL/RT1210: AC energy subsystem and interfaces to rolling stock subsystem. RSSB, London, UK.
- Warrior D, Mullen P and Collingridge-Moore G (2015) Reading's new world-class railway station sets a UK benchmark. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **168(2)**: 67–74, <https://doi.org/10.1680/jcien.14.00058>.